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The purpose of this study was to identify and describe the batting mechanics of a successful baseball power hitter. The subject used in the analysis was a major league player with all-star credentials.

Two Bell and Howell 70DR cameras, supplied with Kodak Ektachrome film, were used to film the subject striking at ten half-speed pitches thrown by a pitcher from the pitcher's mound. Eight of the ten pitches were hit successfully by the subject. The hitting stroke that resulted in the ball being hit with the greatest power was selected by the author for analysis. The film was viewed through a DuKane Cassette Filmstrip Viewer. The acceleration, velocity, and sequential order of movement of selected body segments were analyzed at specific points during the swing.

There were still positive accelerations of the bat, hands, hips, and shoulders at the moment of contact with the ball. Considerable shoulder and hip rotation took place throughout the swing. Hip rotation was restricted somewhat due to the closed stance used by the batter. Contrary to the opinion of some authorities, the closed stance and restricted hip rotation did not seem to adversely affect the generation of power by the hitter.

A CINEMATOGRAPHICAL ANALYSIS OF A
BASEBALL BATTER'S SWING

by

John Wesley Smith, II

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Approved by

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APPROVAL SHEET

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CHAPTER I

INTRODUCTION

Baseball is a game requiring competence in a variety of motor skills and talents if the individual is to achieve success as a participant. Batting is the most difficult baseball skill to master. Every time a player comes to the plate, he is challenged by the pitcher. Whether or not he is successful in this challenge depends largely on his ability to hit the ball. One can see by reading newspapers, magazines, and books that the best hitters in the professional ranks make the most money; therefore, emphasis is put on hitting. The rationale behind wanting good hitters is simple: in order to score runs and win ball games, one must be able to reach the bases and score.

There have been few technical studies of hitting a baseball. The ones that have been conducted usually involve some sort of motion picture done by experts. There have been many biased judgments as to the mechanics of hitting a baseball, but most of these are only opinions based on empirical evidence with very little scientific analysis to substantiate the conclusions. Since hitting a baseball is so important to the game, there is a definite need to know more about it. Obviously, additional scientific analysis of the swing is desirable.

As Williams (3:1) put it, "hitting a baseball is the single most difficult thing to do in sport." Williams said that the continuing frustration of knowing that you are going to fail at your job three out of ten times, if you are a three hundred hitter, contributes to the difficulty in hitting. The ability to make effective contact with a baseball at speeds as high as a hundred miles per hour is to a certain extent a natural gift. The outstanding hitters in baseball often are unable to tell exactly how they do it--they just do it. Hitting a baseball has had no barrage of scholarly treatment, and that is probably why there are so many people teaching it incorrectly.

Movies have not been used in baseball as much as other sports, but films can be instrumental in improving form. Through the use of cinematographical analysis, external movements in hitting a baseball can be determined. A cinematographical analysis of a baseball batter's swing can be beneficial in a number of ways: (a) it can benefit the individual being analyzed, (b) the coach will gain knowledge and be a better instructor in the techniques of batting, (c) some light may be shed on the techniques of batting that can be used to improve an individual's batting performance, and (d) major factors may be discovered that govern the performance of a hitter. Thus, motor performance can be studied and interpreted in terms of recognizable scientific principles instead of opinions and guesswork.

PURPOSE OF THE STUDY

It was the purpose of this study to identify and describe the batting mechanics of a successful baseball power hitter. Specifically, the study involved an analysis of the:

(1) stance

(2) stride

(3) contact with the ball

(4) sequential order of movements of the arms, legs, and body throughout the entire action of the swing.

LIMITATIONS OF THE STUDY

This study was limited in the following ways:

(1) Only one male subject was used.

(2) Only one swing was analyzed.

(3) Certain angles, velocities, and accelerations could not be determined and studied because of the camera position.

(4) The subject was filmed in the off-season.

(5) The pitcher threw half speed pitches to the batter.

DEFINITION OF TERMS

Closed stance. A stance in which the right foot of a left-handed hitter is closer to home plate than the left foot.

Stride. Shifting the weight in the general direction of the pitcher from the back foot to the front foot by means of a step.

Force. The cause that produces, changes, or stops the motion of a body.

Velocity. The change of position of a point per unit of time.

Acceleration. The rate of change in the velocity of a moving body.

Power. The capacity for exerting mechanical force.

CHAPTER II

REVIEW OF LITERATURE

The review of literature is categorized as follows: hitting a baseball, cinematographical techniques and studies, and mechanical principles.

HITTING A BASEBALL

Watts (14) investigated the skill of hitting a baseball. He found that most power hitters held the bat at the very end because the extra length provided more leverage by enlarging the arc in which the bat moved. Watts also found that for every movement of the hitting surface, there was proportionately a greater movement of the hands.

The positions of the hands and fingers may be the key to hitting. Some outstanding hitters have resorted to tucking the little finger of the lower hand under the knob of the bat in an effort to gain added leverage. The longer and heavier bat enables a hitter to drive the ball farther, contingent upon his ability to control the bat. It is safe to say that the stronger the player, the heavier bat he will be able to use, therefore, making hitting a little easier.

Fonseca (8) commented on the shift of the weight in hitting a baseball. He suggested that the body should be shifted forward, but not until the ball is hit, holding maximum power for the crucial moment of contact. In addition, he contended that rotary hip motion is necessary for a good swing. This free flow of weight allows real swing speed, and the hips are literally whipped into motion as the ball hits the bat.

Watts (16), in another publication, stated that rotary motion involving the hip is absolutely essential to the good swing, and that it actually starts the movements of the shoulders. The hip action is the key link in the chain which extends from the start to the finish of the swing. Rotation of the hips not only starts the movement of the shoulders and pulls the weight into the swing properly so that the ball is met with full power, but it leads the body through the continuous flow of motion into a good follow through.

Williams (3) commented that as the bat moves across the plate, the front arm should be held firm and should be straightening out until it is perfectly straight at the point of impact. When the arms straighten out, the swing reaches the point of maximum power. The roll of the wrists occurs at this time and carries this chain of action through to the proper completion.

Mallory concluded that great hitters are born, not made. "No amount of instruction can compensate for God given natural ability of one of your players." (2:65) Some great hitters have unorthodox stances, but one with an unorthodox stance always follows a definite pattern once he is into his swing.

The head should be absolutely rigid in the stance. The left-handed hitter must keep his right eye pinned on the baseball.

If he follows this, things will begin to happen which will improve hitting.

Williams commented that batting has both mental and physical requirements. He listed three musts on the mental side and three musts on the physical side. (15:29) On the physical side, he listed

(a) strong quick hands and wrists were needed in order to whip the bat across the plane of the plate,

(b) weight forward on the balls of the feet,

(c) ability to cover the whole area of the strike zone with the bat.

Williams stressed that the hands and wrists were extremely important in hitting a baseball.

Hubbard (9) found in studying visual movements of batters that most hitters swing late. In studying the start of the stride, finish of the stride, and the swing of the bat, he found that the steps start with preliminary weight shifting before the lead foot comes off the ground. The finish step could be considered as happening before the whole foot is planted solidly. The movement of the bat showed that it moves from the plate. Hubbard stated that the most important part of the swing was when contact was made with the ball.

Williams (3:35) said in his latest publication that the shoulders should be level at the start of the swing, and that the head should be kept motionless. He contended that this can only be done by holding the bat perpendicular to the ground. The bat will feel lighter and more comfortable.

CINEMATOGRAPHIC TECHNIQUES AND STUDIES

The motion picture is the most completely explicit of the media of communication that address the eye, the primary organ of perception. Motion pictures have been used for many years in the study of certain athletic skills because one can visualize the mechanical principles involved in a particular skill.

Smilgoff (12) stated that motion pictures form an objective and reliable means of diagnosing. It was his contention that motion picture photography is the best way in which to improve any skill. Let the individual see himself perform and he will be apt to improve the skill in which he viewed.

Cureton (4) has suggested that fairly precise analysis of the external mechanics of many acts of skill may be made by cinematography. The fundamental principles of direction of movement, dimensions, time relations, and values of force and velocity may all be obtained from projected film. Since the science and mechanics of hitting a baseball is a precise and difficult task, a mechanical analysis of any movement may be made from measurements taken from the screen. Cinematographical analysis consists of the techniques for making these measurements. Thus, athletic performance can be studied in terms of recognizable and scientific principles instead of empirical guesses and vague suppositions which have logically characterized the coaching of sports literature up until very recently.

Eckert (6) used cinematography to find the angular velocity and range of motion in the vertical and standing broad jumps. Seventeen males were analyzed during their performance of the vertical jump under different conditions. Eckert found that maximal angular velocity decreased and there was evidence of increases in the range and time of motion of the hips, knee, and ankle joints with the increasing amount of weight.

Eckert (7), in a more recent study, found that the velocity and range at the hip joint were greater in the standing broad jump and the velocities at the knee and ankle joints were greater in the vertical jump. In relation to this study, movements of the body can be determined by the use of cinematography.

Quandt (10) conducted a study in which he compared the fast ball pitch to that of the palm ball pitch. His purpose was to determine the mechanical differences between two pitches and to develop a more effective way to coach the pitcher in throwing the palm pitch. Without the use of motion pictures, this would not have been possible because the positions of the fingers in gripping the ball were photographed and analyzed afterwards.

Race (11) used cinematography to analyze the external movements in hitting a baseball. In his study, emphasis was placed on (a) forward movements, (b) linear movements, and (c) rotary movements. By using these movements, a number of things could be measured. Hip rotation, movement of the hands, knee measurements, body lean, and head measurements were found through the analysis.

Wrigglesworth (17) found through the use of cinematography that the chip shot in golf could be analyzed effectively. Using two sixteen millimeter cameras at two different angles, five expert golfers were photographed. After processing the film, it was viewed as a movie in slow motion. Tracings were made of the subjects in the following positions: (a) at address, (b) backswing, (c) contact, and (d) the follow through. By using this method, Wrigglesworth was successful in finding the measurements of segmental movements.

DeVries (5) analyzed the dolphin swimming stroke by using two sixteen millimeter cameras. He viewed and analyzed his films by using a thirty-five millimeter slide projector so that he could view both rolls of film at the same time. This in turn gave DeVries a method of comparison of the different movements in his analysis.

Watkins (13) conducted a study in which he used motion pictures as an aid in improving one's hitting ability. Although quite similar to Smilgoff's study, Watkins found that movements of any type prior to the pitch were detrimental to the hitter's success. Watkins also found through the use of cinematography that a baseball player's hitting ability could be improved by viewing the motion picture. Watkins' findings indicated that by viewing a motion picture one's skill could be improved considerably.

SUMMARY

The books and articles read offered little scientific information on hitting a baseball. Although scientific evidence is lacking, one must respect the opinions of the authors because they are considered experts in the field of baseball. Some of the research centered around cinematographical studies and how they were conducted.

CHAPTER III

PROCEDURE

It was the purpose of this study to identify and describe the batting mechanics of a successful baseball power hitter. Specifically, the study involved an analysis of the: (a) stance, (b) stride, (c) contact with the ball, and (d) sequential order of movements of the arms, legs and body parts throughout the entire action of the swing.

SUBJECT

Michael Lynn Carruthers, a member of the Cleveland Indians professional baseball organization, was selected as the subject. The subject was a six-foot three and one-half inch, 227-pound first baseman who has played baseball professionally for the past four years. He has been named an all-star candidate every year of his professional career and is considered as a power hitter by experts. His senior year in college was marked by a .503 slugging percentage.

PREPARATION OF THE SUBJECT

The subject wore a pair of white socks, baseball shoes, and a pair of shorts. He wore no shirt. A black magic marker was used to mark different body parts of the subject. Marks were placed at the following locations:

(1) lateral malleous at each ankle,

(2) medial and lateral aspect of the knee joints,

(3) greater trochanter at the hip where the acetabulum cavity is formed,

(4) proximal end of the radius at the olecranon which forms the elbow joint,

(5) the acromium process of the shoulder joint at the lateral aspect at the head of the humerus.

The hip was marked by taping a three and one-half inch door stop to his belt so that hip rotation could be measured.

FILMING EQUIPMENT

There were two cameras used in the filming of the subject. These cameras are identified as camera number one and camera number two. A large piece of navy blue material was placed in the background of the first camera, so movements of the body could be easily viewed. A yardstick was placed on this backdrop so that a conversion factor could be calculated from camera number one. A plumb line was placed in the background to provide a true vertical line as a reference point in analyzing the film.

Two Bell and Howell 70DR cameras supplied with Kodak 7242 Ektachrome film were used in the filming of the subject. This type film is especially designed for high speed filming and is balanced for tungsten light. Camera number one was equipped with a twenty-five millimeter lens set at f 11 and a shutter speed of

1/15th of a second. Camera number two was equipped with a ten millimeter wide angle lens so that perspective error could be minimized. The lens was set at f 11 and the shutter speed remained at 1/15th of a second.

FILMING PROCEDURE

Camera number one was placed to the third base side of home plate, eighteen feet away from the subject. The camera was placed on a tripod and locked into position. Camera number two was positioned six feet above the batter's head. It was positioned on a ladder which rested horizontally on two other ladders. See Figure 1, page 15, for layout.

The subject was instructed to run a few laps and to perform a few stretching exercises in preparation for batting. The filming took place at the Greensboro War Memorial Stadium located on Bagley Street in Greensboro, North Carolina. The temperature at the time of filming was forty-two degrees with a slight wind out of the northwest.

At the completion of the subject's pre-performance exercise period, he was taken into the dressing room where he was marked for the filming. The subject was given an unknown number of pitches in order to adjust his timing. When the subject felt he was ready to be filmed, the photographers readied themselves for the filming procedure. The pitcher stood on the pitcher's mound and threw to the subject. He was told to throw the ball half speed, which would

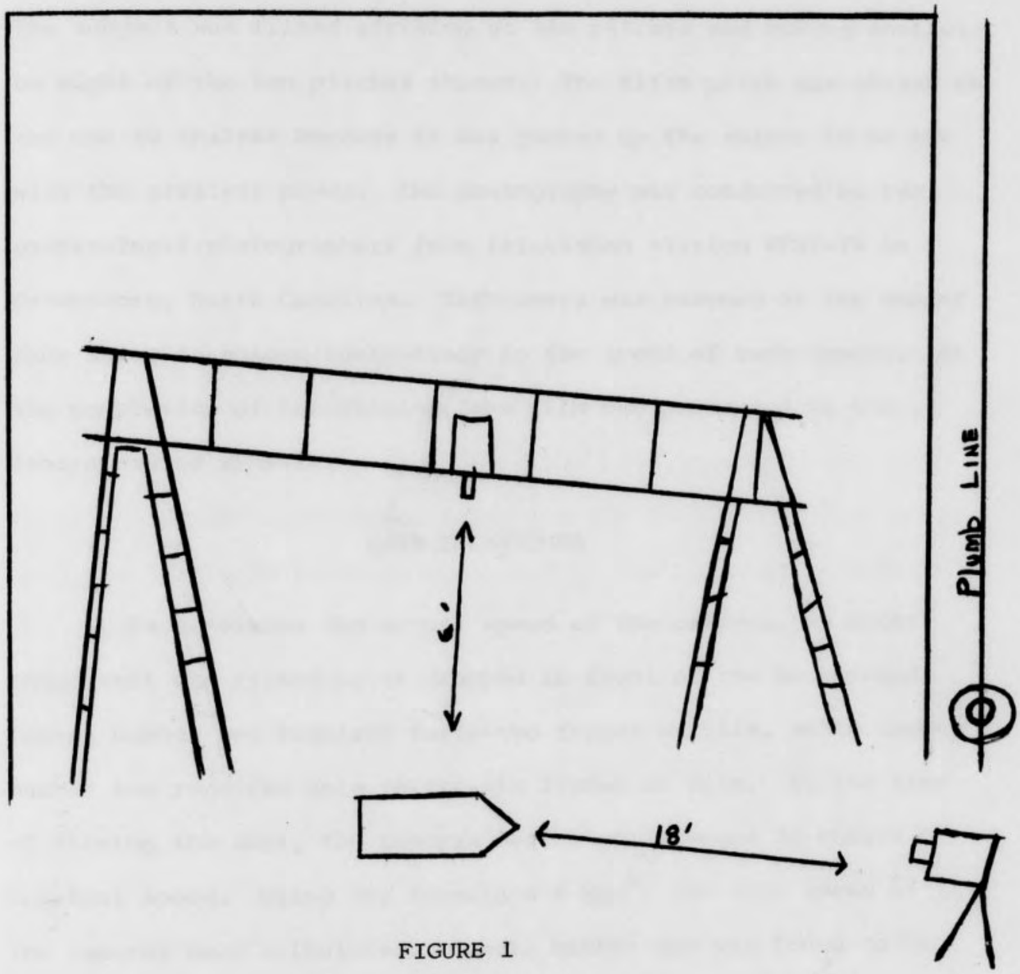

FIGURE 1

LAYOUT OF THE FILMING AREA

give the subject a better chance to make contact with the ball. The subject was filmed striking at ten pitches and making contact on eight of the ten pitches thrown. The fifth pitch was chosen as the one to analyze because it was judged by the author to be hit with the greatest power. The photography was conducted by two professional photographers from television station WFMY-TV in Greensboro, North Carolina. The camera was rewound at the end of each swing to ensure consistency in the speed of each camera. At the completion of the filming, the film was processed in the laboratory of WFMY-TV.

DATA TECHNIQUES

To determine the actual speed of the cameras, an eight pound shot was filmed as it dropped in front of the background. Camera number one required forty-two frames of film, while camera number two required only thirty-six frames of film. At the time of filming the shot, the cameras were tightly wound to ensure constant speed. Using the formula $S = \frac{1}{2}gt^2$, the true speed of the cameras were calculated. Camera number one was found to be filming at sixty-four frames per second, while the speed of camera two was found to be approximately fifty-nine frames per second.

After processing the film, the films were viewed frame by frame through the use of a DuKane Cassette Filmstrip Viewer. Selected frames were chosen and traced onto Aquabee Tracing paper where angles, velocities, and accelerations were measured. With the plumb line being used as the vertical reference and the bottom of the cloth serving as the horizontal reference for camera number one, measurements were then calculated. Home plate was used as the reference point for camera number two. A ruler, compass, and protractor assisted in the calculations.

The angles of the knee, hips, shoulders, and elbow joints were calculated. The body lean was also determined by measuring the mid-point of the batter's feet and then drawing a line from that point to a point on the top of the rear shoulder.

Average velocity was found for the shoulders, hips, hands, bat, and the right or leading arm. This was computed by using the formula,

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}} .$$

Projected images on the screen are usually not lifesize, therefore, a conversion factor had to be found. The conversion factor for camera number one was found by using the yardstick in the background as the reference point. The subject was filmed in a position halfway between the camera and the backdrop. The conversion factor for camera number two was found by using home plate as the reference point. Since home plate could not be positioned the same distance the camera was from the batter, the conversion factor had to be computed. The conversion factor for camera number one was one and one-half inches equals one foot. Camera number two was found to be one inch equals eight inches.

Velocity measurements for the leading arm, bat, and hips were calculated at critical points of the swing, one being at the moment of contact.

Acceleration measurements were also calculated at critical points of the swing including the point of bat contact with the ball.

CHAPTER IV

ANALYSIS OF DATA

The data were analyzed in relation to the sequential order of the swing with emphasis placed on the stance, stride, and contact with the ball. Measurements were found in terms of selected angles, velocities, and accelerations.

STANCE

The stance was the position of the batter as he awaited the delivery by the pitcher, Figure 2, page 20. The subject chose a position in the batter's box and used a closed stance. A closed stance is a stance in which the front foot is nearer home plate than the rear foot. The heel of the subject's front foot was in line with the toe of his rear foot, while the toe of his right foot pointed toward the pitcher at a 142 degree angle toward the pitcher. The batter's toe was pointing in the direction of the stride. The subject was in a crouched position with a body lean of 97 degrees away from the pitcher. This measurement was found by drawing a vertical line to the top of the head from the midpoint found between the batter's feet. The arms were held away from the body with the angle of the right arm, at the shoulder, 60 degrees from a line drawn through the midpoint of the shoulders.

FIGURE 2

THE STANCE

The angle of the shoulders was 63 degrees when the mark of the left shoulder was used as the vertex.

BACKSWING

In .23 of a second after movement in the backswing, the angular positions of the shoulders and arms were found to vary little in measurements from the body position found in the stance of phase one of the swing. During this phase of the swing, the body moved laterally away from the pitcher with the batter's two feet remaining in a stationary position. The shoulders had moved laterally away from the pitcher at the rate of 1.00 feet per second. The right arm went through a lateral adduction at a linear velocity of 0.88 feet per second. From these velocity and angular measurements of the shoulders and right arm, it was found that linear movement had begun, but angular movement of the shoulders and right arm was not evident at this time of the backswing. The upper and lower aspects of the left arm were held parallel to the ground, just below the shoulder line. The angle of the bat at this point of the backswing was 69 degrees, some three degrees less than what was found in the stance. The bat was found to be moving away from the pitcher at an angular velocity of .209 Radians per second. With the bat at a 69 degree angle, excessive movements of the hands and wrists could be expected. A bat is designed with the greatest amount of mass located at the distal end. With this in mind, it is the opinion of the writer that more torque would be placed on the wrists and hands when the mass of the bat is not directly over the hands.

The hands were moving away from the pitcher at a linear velocity of 3.05 feet per second during the backswing. This occurred .67 of a second after the backswing had begun. The position of the bat at the completion of the backswing was found to be 67 degrees. At this point of the swing, more torque was being placed on the hands than the previous measurement. If bat control can be maintained at this point of the swing, more momentum can be developed by the batter due to the greater the arc of the implement. The leading arm was still moving away from the pitcher at an angular velocity of .73 Radians per second in relation to the backswing.

STRIDE

The beginning of the stride was designated as the frame in which the heel of the right foot started to rise, Figure 3, page 23 and Figure 4, page 24. The greatest amount of movement took place in the hips as they continued their lateral movement and rotation counterclockwise. The hips moved at an angular velocity of 1.89 Radians per second at this point of the stride. This was found by measuring the number of degrees the hips had rotated in relation to the marks that were placed on the hips prior to the filming. At this point of the stride, the hips had rotated at a faster rate than any other body part. It was assumed that the

FIGURE 3

BEGINNING OF THE STRIDE

FIGURE 4

BEGINNING OF THE STRIDE

batter's body had begun its initial effort to overcome its inertia in order to start the forward movement. The angle of the right arm had decreased to 41 degrees with an average angular velocity of .33 degrees per second. This angular movement of the leading arm had in turn caused an increase in the angle of the bat. The arms rotated laterally away from the pitcher, while the hands moved in toward the body at a linear velocity of 4.42 feet per second. The increase in the angle of the bat would suggest that the subject was beginning to initiate the forward movement of the bat, however, that was not the case. The increase in the angle of the bat was due to the inward movement of the hands and their position in relation to the bat handle.

The point of the stride in which the wrists were beginning to cock can be seen in Figure 5, page 26. The average linear velocity of the hands was 10.73 feet per second away from the pitcher with an acceleration rate of 3.84 feet per second per second. The hands moved at a much higher rate than the hips at this particular point of the swing. The hips completed rotation counterclockwise with the weight of the body on the back foot. This appeared to be the situation because at this time the batter's front foot was completely off the ground. The hips at that point of the swing moved at an average angular velocity of 2.05 Radians per second with an acceleration of 17 degrees per second per second. The shoulders had rotated to an angle of 54 degrees. The movement of the shoulders was caused by the arms as they carried

FIGURE 5

BEGINNING OF WRIST COCK

the bat back in preparation for the forward swing. The shoulders had rotated through a greater distance than the hips, but at that particular point of the swing the hips were moving at a greater velocity. The greater velocity of the hips was caused by the coil action which took place just prior to the forward swing. The coil of the body places stretch on the powerful trunk muscles which act as stabilizers, thus placing them in a position for their most powerful effort. The total movement of the front foot in the stride was 10.5 inches. At that point, the batter had moved the bat handle in toward the body. The movement just described increased the arc in which the bat traveled.

SWING

The forward swing began when the trunk, hips, hands and shoulders started to move forward toward the pitcher. At that point of the swing the bat was brought through an arc in the direction of the pitcher. The rotation of the body in the direction of the pitcher was used to transfer the weight of the body. In addition, it built up velocity so contact with the ball would occur at or as near maximum as possible.

The hands had moved at an average linear velocity of 27.29 feet per second since the stride had begun. The upper part of the body had moved forward in relation to the hands. With the hands carrying the bat through the arc toward the pitcher, clockwise forward rotation of the upper arm and shoulders was found. Angular velocity of the bat was determined at this point of the swing by using the right wrist as the reference point. The bat moved at an average angular velocity of 7.39 Radians per second. The bat moved 73 degrees in 0.058 of a second. The lower extremities, the legs and feet, also moved along with the rest of the body parts. The shoulders moved at an average angular velocity of 1.11 Radians per second, while the hips moved at an average angular velocity of 2.29 Radians per second. The amount of rotation found in the hips was dependent on the position of the front leg at the completion of the stride. The batter, at the end of the stride, was in a closed stance position. The amount of hip rotation was decreased because the front foot locked the hip in position. The front foot was positioned on the ground in front of and away from the body. The knee of the right leg moved in the direction of the pitcher at an average linear velocity of 14.85 feet per second. The rapid movement of the knee at this point in the swing was due to the thrusting of the knee outward to facilitate hip rotation.

The rear leg started its pivot in order to facilitate rotation of the hips at an even greater velocity when the front foot had made contact with the ground. The batter's body had moved toward the pitcher and the weight of the body was being transferred from the back foot to the front foot during the stride.

At the beginning of the swing the front foot had contacted the ground to establish a wide base of support for the swing. This wide base of support gave the subject the necessary equilibrium to complete the swing. The foot was positioned at a 145 degree angle from a line drawn through the batter's foot and a horizontal reference found in the margin of home base. Thus, from that point of the swing, the batter was still in a closed stance position.

Acceleration Measurements of the Swing

During the process of the swing, there were eleven frames found to make up this part of the analysis. This made it necessary to calculate accelerations by comparing every other frame. All selected body parts had begun their initial movement forward in the direction of the pitcher at the completion of the stride. Acceleration measurements were made at the following points: (1) from the start of the swing to one-half the way through the wrist cock of the batter; (2) from one-half the way through the wrist cock to three-fourths of the way through the wrist cock of the batter; and (3) from three-fourths the way through the wrist cock until contact was made with the ball.

From the start of the forward swing to the point of one-half through the wrist cock, all body parts selected to be measured were undergoing positive acceleration. This includes the shoulders, hips, hands, bat, and leg. The hands continued to move at the greatest velocity, 29.72 feet per second, with a positive acceleration of 2.43 feet per second per second. As the hands were accelerating positively, the bat was brought through its arc with an angular velocity of 8.87 Radians per second. The acceleration of the bat was found to be 1.48 Radians per second per second. This increase in the velocity and acceleration of the bat and hands was due to the sequential order of movement of the hips, shoulders, arms, and stride. The shoulders moved at an angular velocity of 2.34 Radians per second with a positive acceleration of 1.23 Radians per second per second. The shoulders had to rotate at a greater velocity as the hands brought the bat around with increasing velocity and acceleration. The hips rotated at an angular velocity of 3.94 Radians per second with an acceleration of 1.65 Radians per second per second.

At three-fourths the way through the wrist cock of the swing, the velocity and acceleration measurements were found to have increased. Although this phase of the swing was of shorter duration, velocity and acceleration measurements increased from the previous phase which was of longer duration. From this analysis it was evident that as the time of contact drew nearer, velocity and acceleration measurements increased from the previous phase. Again, the hands were moving at a greater velocity and acceleration than any other body part. The hands moved at a linear velocity of 11.33 Radians per second with a positive acceleration of 2.46 Radians per second per second. There was an increase in the velocity and acceleration of the hands and bat compared to the hip data of 2.08 Radians per second per second for the acceleration and 6.08 Radians per second for the average angular velocity. The increase in the hip velocity indicates that the subject put forth the greatest effort in rotating his hips at that point of the swing just prior to contact with the ball. The velocity of the shoulders was 3.75 Radians per second with an acceleration of 1.41 Radians per second per second compared to the hips which were substantially more. These data that was found indicated that the hips moved at the greatest speed.

CONTACT

Contact was the point in which the bat and the ball met at full force. At the point of contact, the bat moved at an angular velocity of 12.32 Radians per second. At the moment of contact, the bat was still undergoing positive acceleration at the rate of .99 Radians per second per second. From this calculation, it can be assumed that at the point of contact maximum velocity of the bat had not been reached. Not only was this true for the bat, but was also true for the hands, hips, and shoulders. This simply meant that the batter made contact with the ball too soon. The linear velocity of the hands at the point of contact was 32.58 feet per second with an acceleration of .76 feet per second per second. The hips were found to be moving at an angular velocity of 6.83 Radians per second with an acceleration rate of .75 Radians per second per second. The data found in the acceleration measurements were decreasing, but at the same time undergoing positive acceleration. In order to be undergoing negative acceleration, the acceleration rate would have to be less than zero. From the calculation of the hands it, in a sense, was evident that the hands and hips were undergoing acceleration with only a difference of .01 of a foot. The shoulders were moving at an angular velocity of 4.17 Radians per second with an acceleration of .32 Radians per second per second. Since the selected body parts were still undergoing positive acceleration, this meant at the point of contact the body parts analyzed in this study were not at maximum velocity. The acceleration was decreasing but had not yet reached the point of zero in any case. Hip rotation was found to be much greater than that found in the shoulders. This could come from the immobility placed on the joints in the shoulders that come from the well developed pectoral muscles. The bat moved at a higher acceleration rate than any other angular measurement at the point of contact. This could possibly come from the quickness found in the subject's hands as the bat followed its arc. The ball at contact was pulled down the right field line which meant that the batter "got in front of the pitch."

IMPLICATIONS

The batter assumed a closed stance and at the end of the swing he was still in a closed stance. The hips are to be opened thereby facilitating greater hip rotation. Watts (16) found that rotary hip motion is an essential element to the good swing, especially for a power hitter. From the findings of this study, this is not true. This study found that a power hitter can hit with power and not have good rotary hip motion.

From the measurements found in the analysis, the hands moved at a greater rate than the hips. Watts (16) also found that most power hitters held the bat at the very end. By holding the bat at the end, more leverage was provided and the arc in which the bat traveled was increased. From the measurements calculated in this study, the hands moved 32.58 feet per second. The quickness of the hands was of sufficient speed to provide the batter with the power he needed to pull the ball.

CHAPTER V

SUMMARY, RESULTS AND RECOMMENDATIONS

It was the purpose of this study to identify and describe the batting mechanics of a successful baseball power hitter. The subject used in this study was Michael Lynn Carruthers, a member of the Cleveland Indians baseball organization. He has excellent credentials in baseball being an All-American in college and also being named as an all-star candidate every year of his professional career. Carruthers is considered by baseball experts as a power hitter. His senior year in college, he had a slugging percentage of .503.

There were two cameras used in the filming of the subject. Both cameras were Bell and Howell 70DR cameras supplied with Kodak 7242 Ektachrome film.

The cameras were placed in a fixed position during the filming. Camera number one was placed eighteen feet to the third base side of the subject. Camera number two was placed directly over the head of the subject at a distance of six feet. Three ladders were used to construct a scaffold so the photographer could be positioned directly over the head of the subject. A dark blue backdrop made of muslin was used so that measurements would be easier to compute. After the equipment was in the proper position, the subject was instructed to run a few laps and perform a few stretching exercises. The subject was then marked and given a few practice swings. A pitcher threw to the subject from the pitcher's mound at half speed. The subject was filmed striking at ten pitches, but making contact with the baseball only eight of the ten times. The swing at the fifth pitch was used for the analysis because, judged by the author, this was the pitch that was hit with the most power.

After processing the film, it was viewed through the use of a DuKane Cassette Filmstrip Viewer. The selected frames were chosen and traced onto Aquabee Tracing paper where angular velocity and accelerations were measured.

The results of the analysis were of keen interest. The body parts and segments analyzed were found to be undergoing positive acceleration at the point of contact. This proves that at the moment of contact, maximum velocity had not been reached. From this study, it was evident that a batter can hit with power even if hip rotation was hindered. In this case, it was due to the quickness found in the subject's hands as they whipped the bat around in preparation for contact with the ball.

It would be worthwhile if more studies would be made in this area in order to get a wide variety of subjects. This would also make way for evidence and proof of the mechanics of hitting a baseball with power.

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APPENDIX

TABLE I

MEASUREMENTS FOUND DURING SWING

	Angular Velocity	Linear Velocity	Acceleration
(A) Start of forward swing to one-half wrist cock			
Hands	x	29.72	+2.43
Bat	8.87R	x	+1.48R
Shoulders	2.34R	x	+1.23R
Hips	3.94R	x	+1.65R
(B) One-half wrist cock to three-fourths wrist cock			
Hands	x	32.58	+2.86
Bat	11.33R	x	+2.46R
Shoulders	3.75	x	+1.41R
Hips	6.08R	x	+2.08R
(C) Three fourths wrist cock to contact			
Hands	x	32.58	+ .76
Bat	12.32R	x	+ .99R
Shoulders	4.17R	x	+ .32R
Hips	6.83R	x	+ .75R